Template Alignment Optimization in Additively Manufactured Piezoelectric Ceramics

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Sonar transducer performance is greatly impacted by the microstructural alignment of the ceramics from which they are fabricated. Textured ceramics are a desirable material source for these parts because their deliberately aligned microstructures allow for tailored anisotropic properties that rival those of single crystal ceramics, but they also maintain the mechanical robustness and bulk manufacturability of polycrystalline ceramics. Current methods for manufacturing textured ceramics, e.g. tape casting, severely limit design freedom and require excess material waste, and so the advantage of texturing has not been fully realized.

This study is focused on the enhancement of direct ink writing of textured ceramics. Direct ink writing is an additive manufacturing (AM) technique that enhances design freedom on a macro and micro scale and reduces waste by producing near-net shape textured ceramics. However, shear stresses during the AM process affect the microstructural alignment of the ceramic in an extremely complex manner that is difficult to control directly. It is hypothesized that alignment could be optimized by tuning the geometry of the printing nozzle and print parameters (such as extrusion speed), but it would be prohibitively expensive and time-consuming to perform an exhaustive search through all possible geometries and parameter values. This study presents the development and validation of an automation tool designed to significantly accelerate the parameter refinement process. First, a computational fluid dynamics (CFD) model that simulates the printing process and produces a novel alignment metric is validated against real-world data. Then, an optimization algorithm is used to maximize alignment with respect to the nozzle geometry.